SEAR Wastewater Treatment: Contaminant Removal and Material Recovery

U.S. Environmental Protection Agency

National Risk Management Research Laboratory

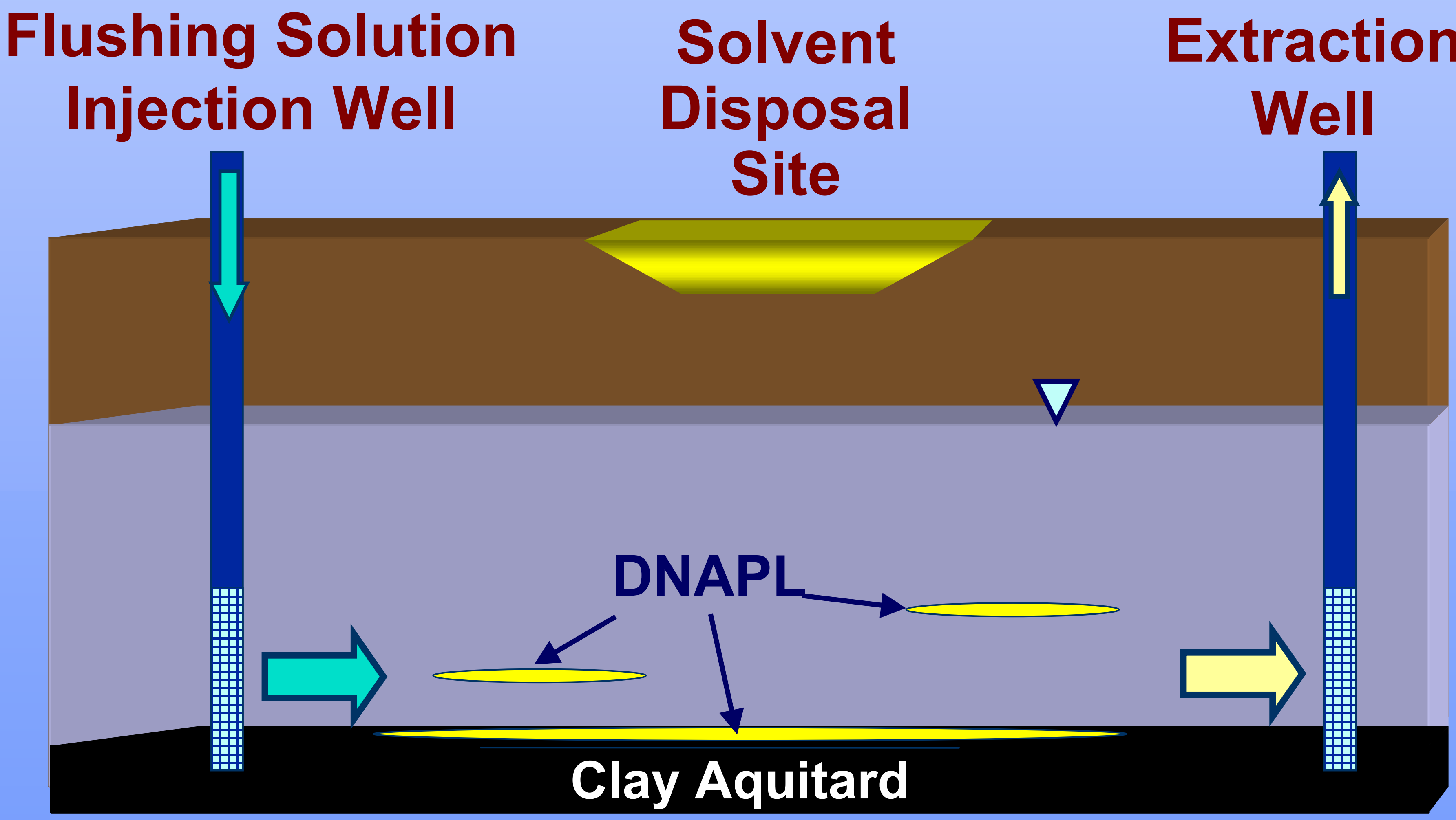
Cincinnati, Ohio

SEAR Workshop

Outline

- Motivation for Treatment
- Contaminant Removal Options
- Surfactant Recovery Options
- Co-Solvent Recovery Options
- Case Study
  - ESTCP Demonstration at MCB Camp Lejeune
- Conclusions

In Situ Soil Flushing/Flooding



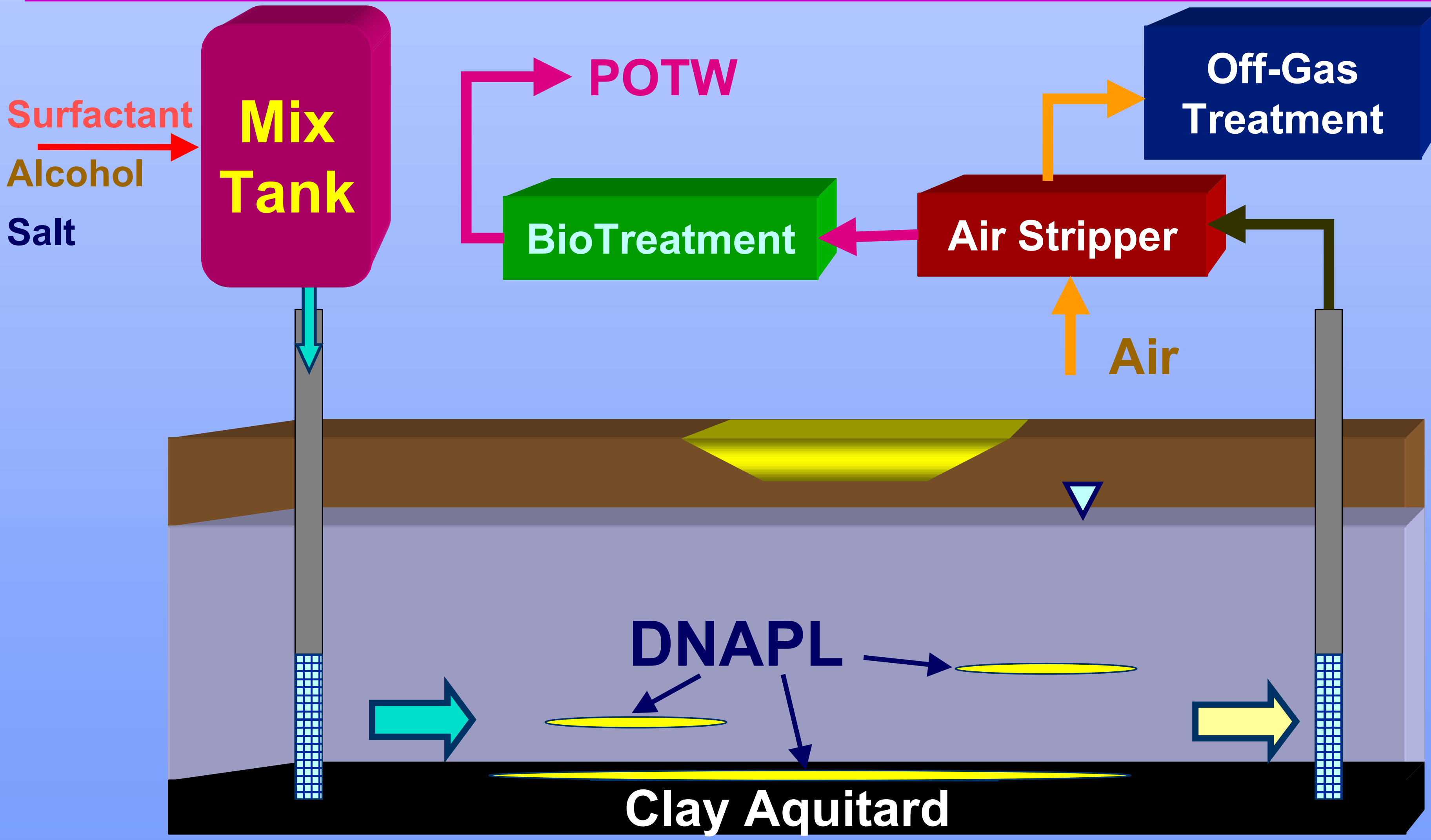
Example Properties of Extracted SEAR Fluid

- Surfactant = 0 to 6 wt%
- Alcohol = 0 to 6 wt%
- Contaminant = 0 to 10,000 mg/L
- pH = 4 to 8
- Ca^{2+} and/or Na^{+} = 0 to 250 mg/L
- Fe^{2+} = 0 to 20 mg/L
- Extraction rate > injection rate

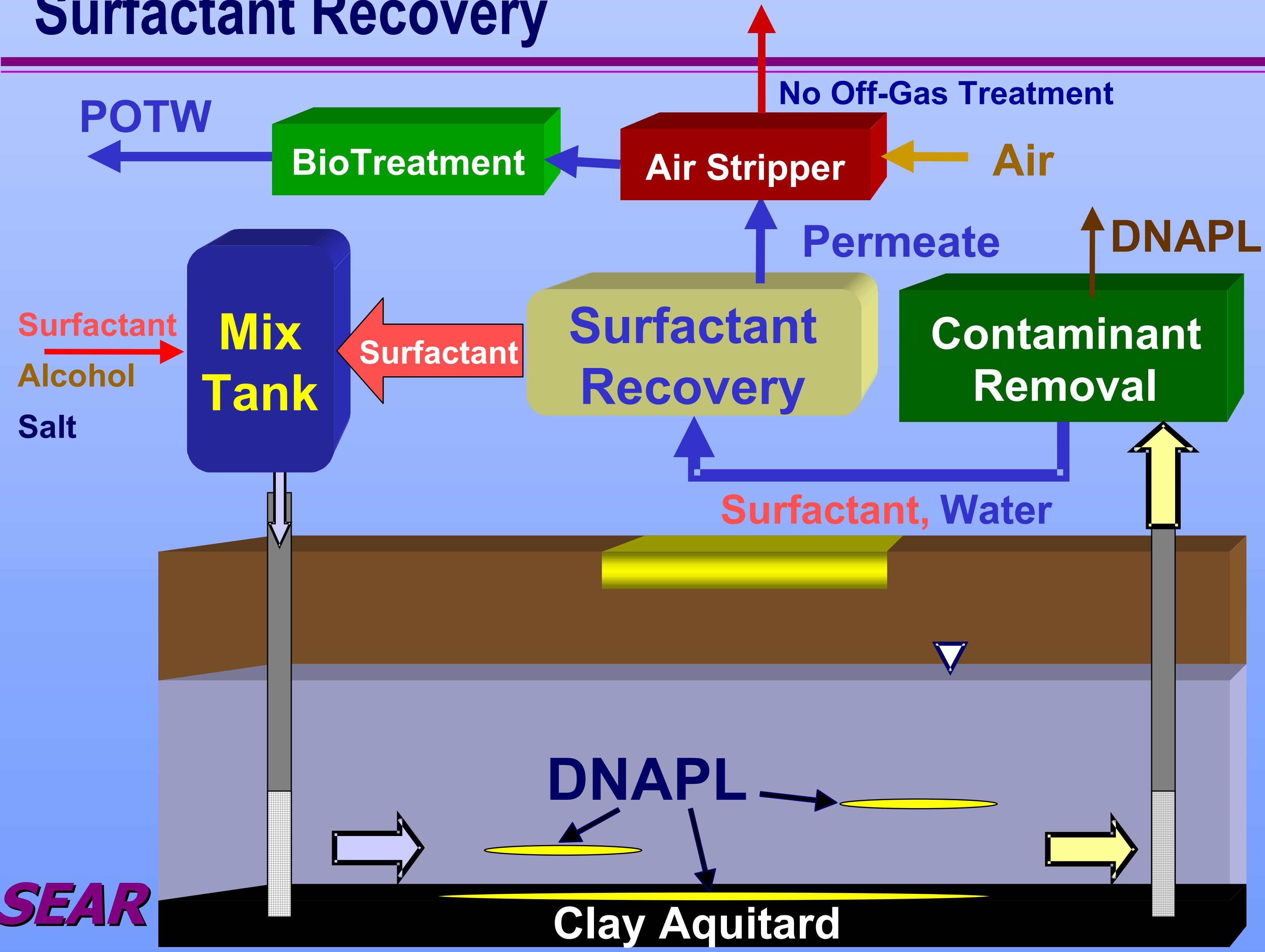
Motivations for Treatment

- Disposal Constraints at Site
  - BOD/COD
  - Hazardous compounds
  - Nuisance foam
- Desire/Requirement to Reuse Surfactant and/or Co-Solvents
  - Material savings
  - Cost savings

Basic Wastewater Treatment Without Surfactant Recovery



Wastewater Treatment With Surfactant Recovery



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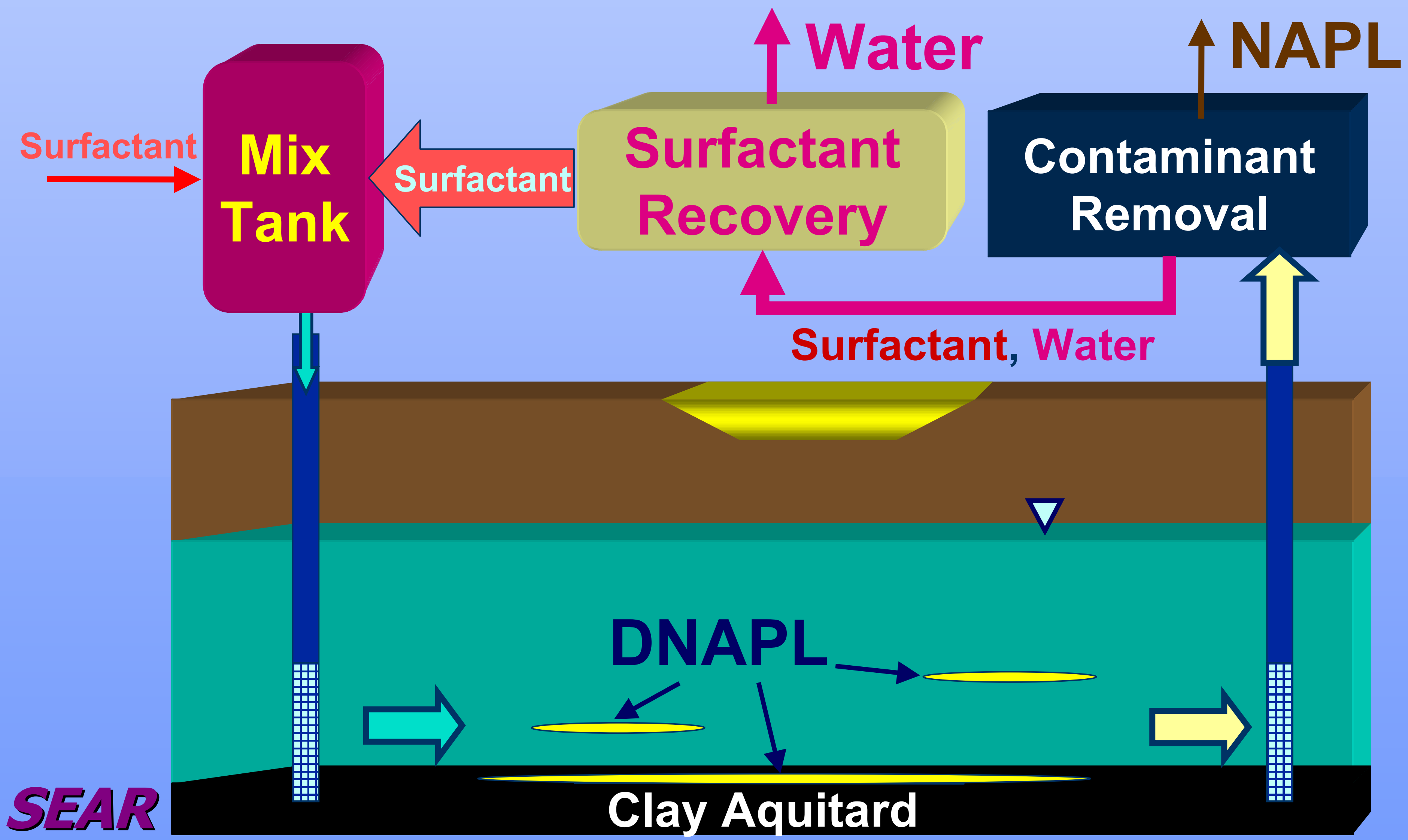
Material Recovery Example: Assumptions

- Surfactant Cost = $5/lb-active
- Surfactant Injection Concentration = 4.0 wt%
- Surfactant Recovery Cost = $4 per 1,000 gallons
- Contaminant Removal Cost = $29 per 1,000 gal
- Surfactant Injection Rate = 4 gpm
- Extraction Rate = 10 gpm
- Single-Pass Recovery of Surfactant = 85%
- Single-Pass Surfactant Soil Losses = 10%

Surfactant Recovery Economics



Material and Cost Savings Spreadsheet

Contaminant Removal Expenses ($/1000 gal)	29.00
Disposal Costs for Surfactant Solution ($/gal)	0.50
Surfactant Cost ($/lb active)	5.00
Surfactant Recovery Expenses ($/1000 gal)	4.00
Recovery of Surf. (% of feed to UF)	85
Single Pass Soil Loss of Surf. (as % of surf. fed)	10
Surfactant Injection Concentration (wt%)	4.00
Injection Flow Rate (gal/min)	4
Extraction Flow Rate (gal/min)	10
Density of Fluid (lb/gal)	8.33

Surf. Conc. in Extracted Fluid (wt%) =	1.44
Feed Rate of Surfactant (lb/day) =	1919.23
Surfactant Extraction Rate (lb/day) =	1727.31
Surfactant Recovered (lb/day) =	1468.21
Add. Surf. Needed for Reinjection (lb/day) =	451.02
Material Savings =	77%
Cost of Surfactant with recycle ($/day) =	2255.10
Cost of Surfactant without recycle ($/day) =	9596.16
Cost of Pervap ($/day) =	417.60
Cost of Ultrafiltration ($/day) =	57.60

Total Cost with Recycle ($/day) =	2730.30
Surf. Cost Without Recycle - no disposal ($/day) =	9596.16
Cost Savings =	71.5%
Annual Savings ($) =	2.51E+06
Potential Disposal Costs for Surf. Solution ($/day) =	7200.00

Result #1: ***Material*** Savings

Surfactant Injected = 1,900 lb/day

Surfactant Recovered = 1,500 lb/day

77% Material Recovery

Result #2: *Cost* Savings

- Surfactant Cost without Recycling = $9,600/day
- Total Cost with Recycling = $2,740/day
  - Fresh Surfactant = $2,260/day
  - Surfactant Recovery = $60/day
  - Contaminant Removal = $420/day

72% Cost Savings

$2.5 million saved per year

Disposal Cost Avoidance: Up to $7,200/day

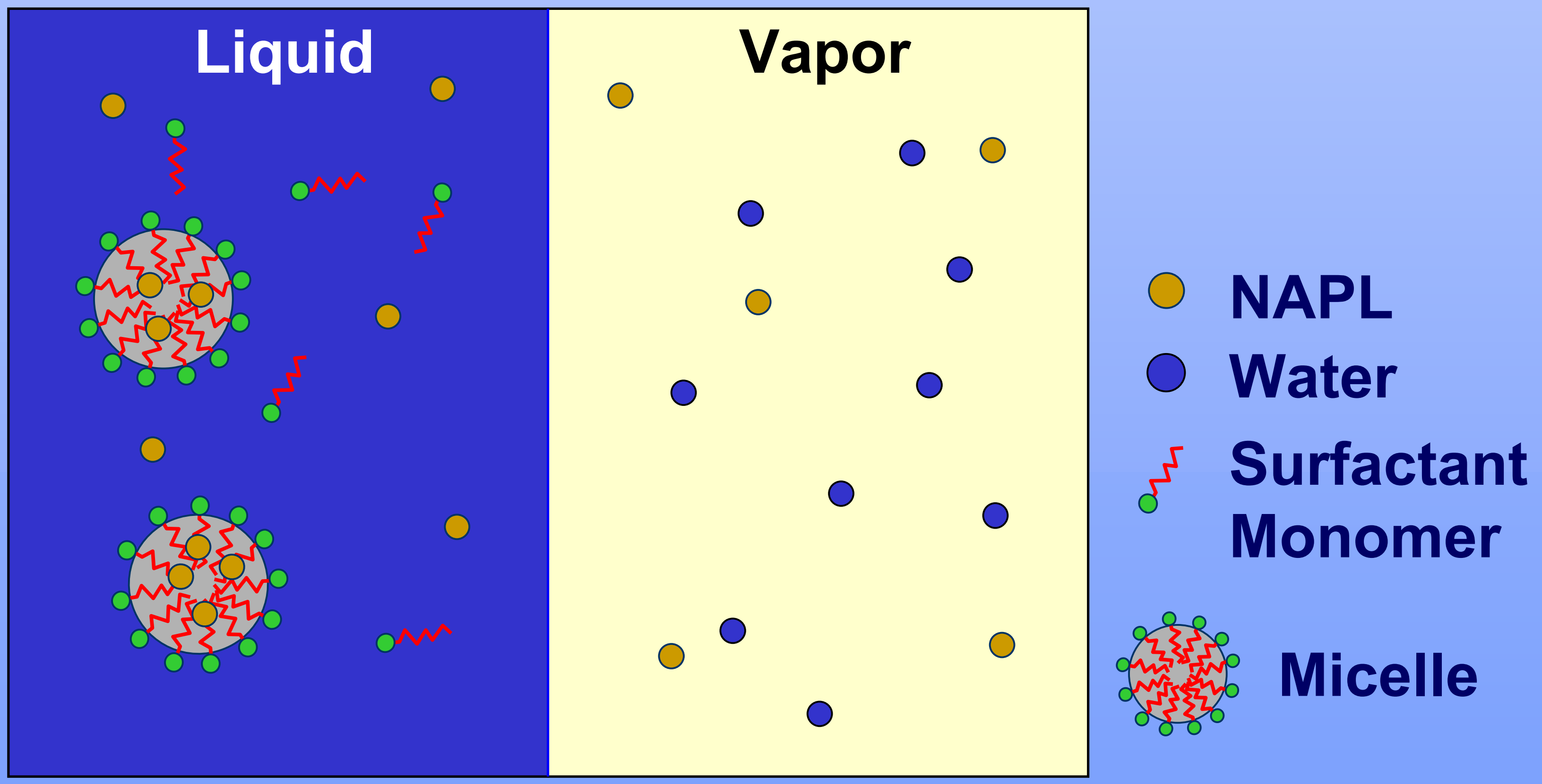
Complicating Factors

- Other streams to be treated
- Additional technologies to be operated
  - Logistics
  - Staff inexperience
  - More things to go wrong

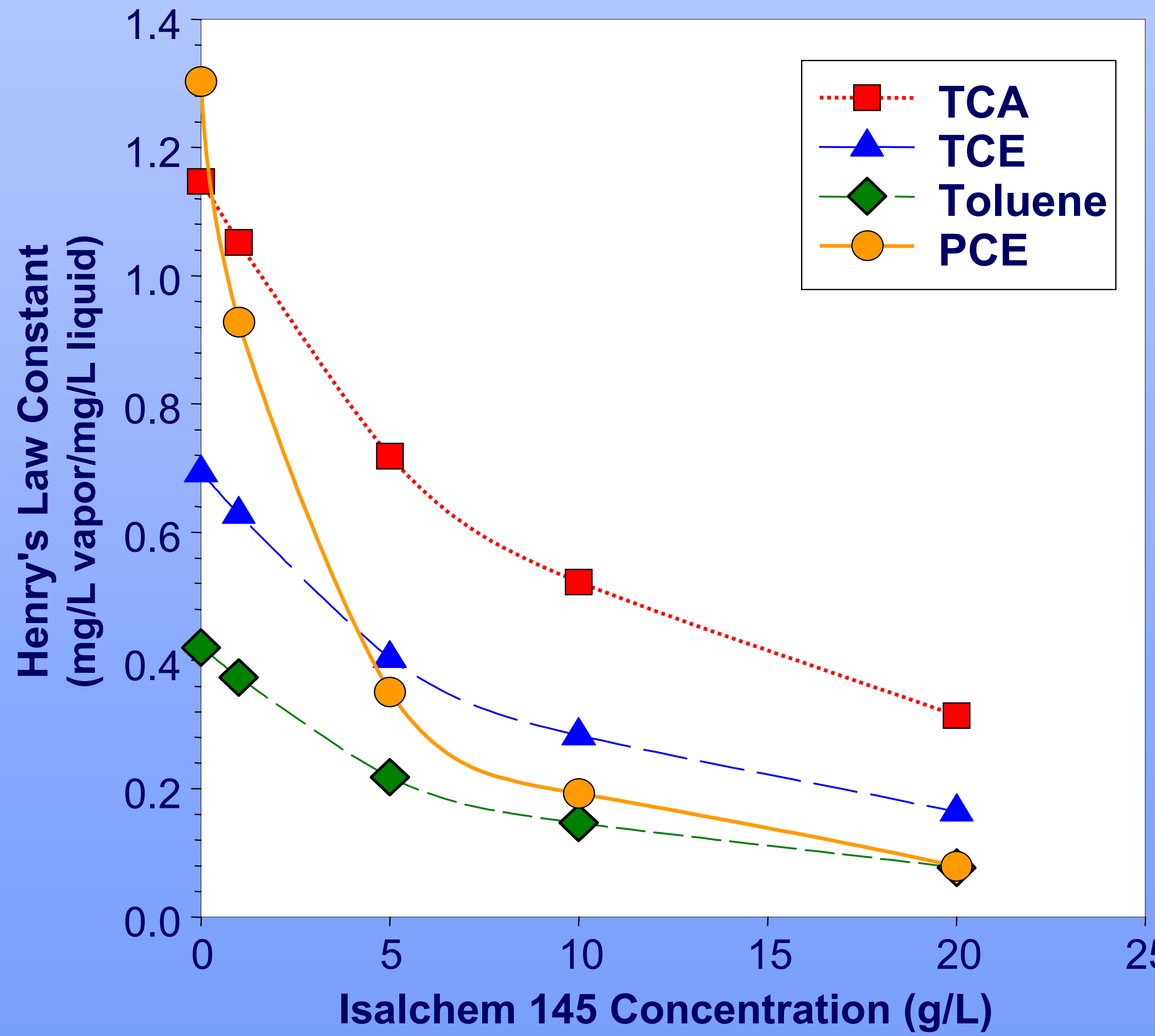
Contaminant Removal Technologies

- Air Stripping
- Steam Stripping
- Pervaporation
- Vacuum Stripping
- Catalysis/Reaction
- Distillation
- Liquid/Liquid Extraction
- Adsorption or Absorption
- Precipitation (of surfactant)

Vapor-Liquid Stripping Processes: Air, Steam, Vacuum



Surfactant Reduces Henry's Law Constant



Air Stripping

- Contaminants
  - Volatile
- Advantages
  - Low cost
  - Deep experience base
- Disadvantages
  - <u>Foaming</u>
  - Off-gas treatment required
  - Poor alcohol removal

Steam Stripping

- Contaminants
  - Volatile and semivolatile
- Advantages
  - Mature technology
  - Applicable to range of contaminants
- Disadvantages
  - <u>Foaming</u>
  - More expensive

Liquid/Liquid Extraction

- Contaminants
  - Volatile, semivolatile, non-volatile
- Advantages
  - Applicable to range of contaminants
  - No foaming
- Disadvantages
  - Stability of interface
  - Emerging technology
  - More difficult regeneration

Adsorption/Absorption

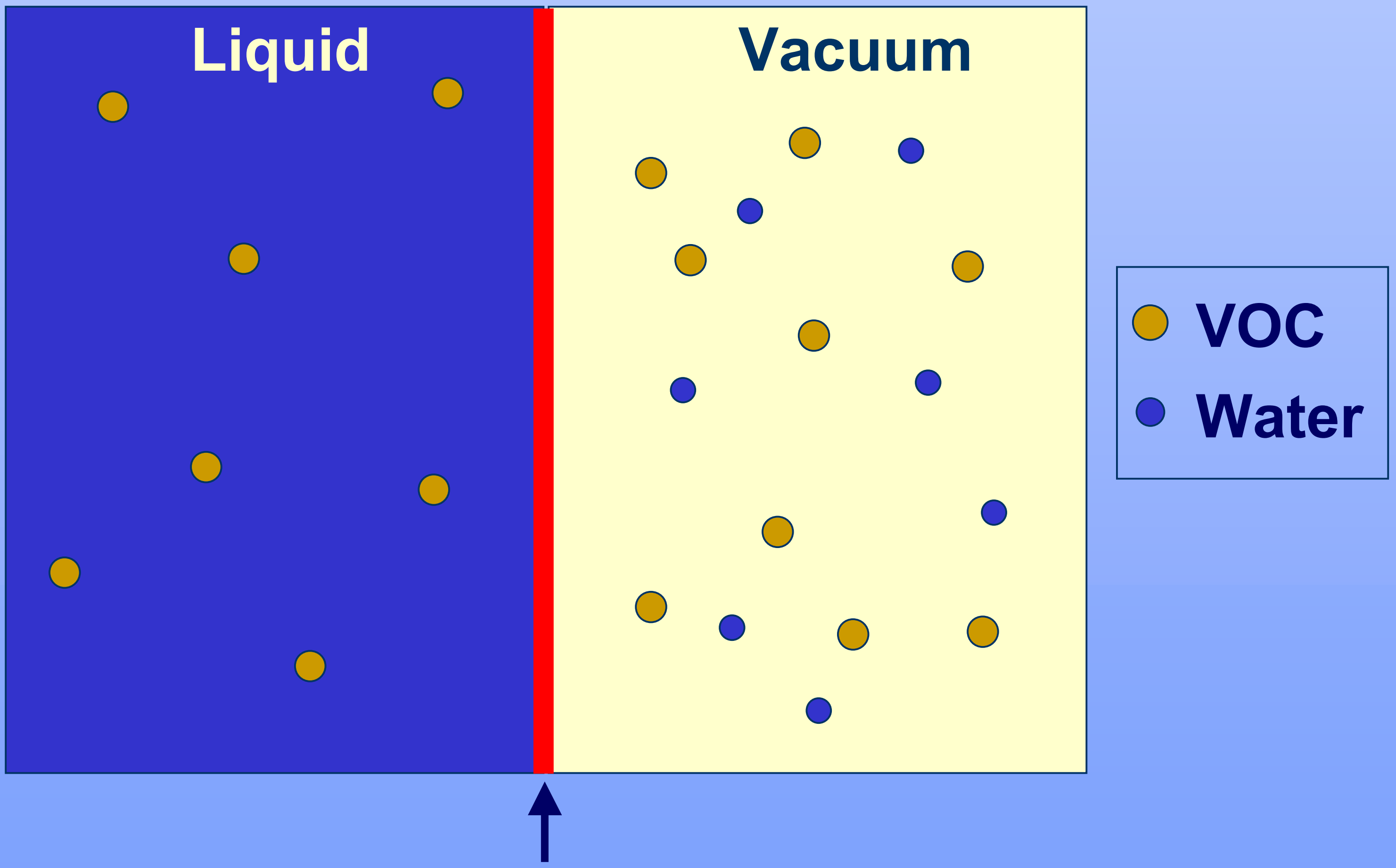
- Contaminants
  - Volatile, semivolatile, non-volatile
- Advantages
  - Applicable to range of contaminants
  - No foaming
- Disadvantages
  - Stability of sorbent
  - Regeneration more complicated

Pervaporation

- Contaminants
  - Volatile
- Advantages
  - No foaming
  - Can be used for alcohol recovery
  - Fouling resistant (if designed properly)
- Disadvantages
  - Emerging technology
  - More expensive than air stripping

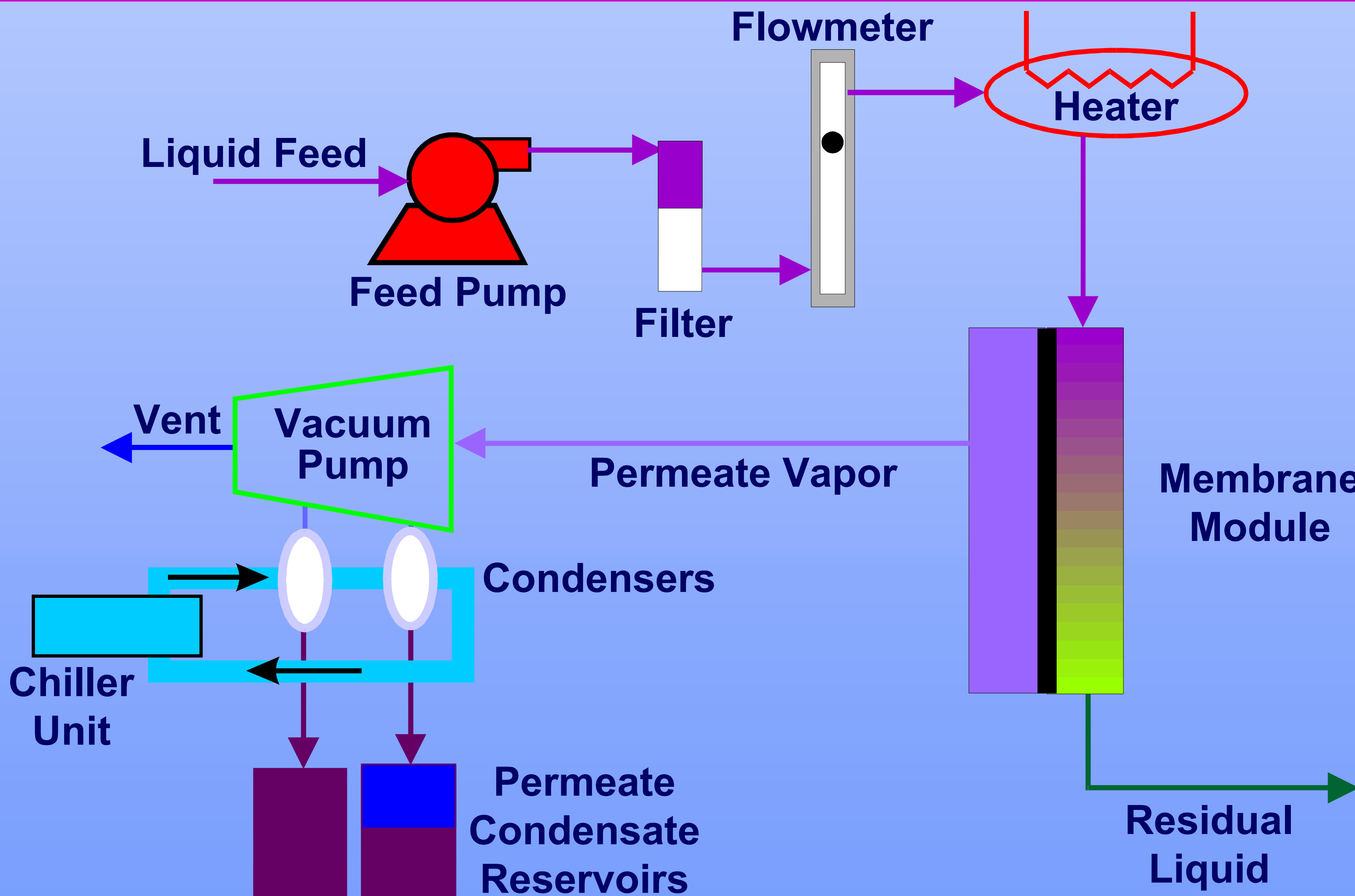
Pervaporation = Permeation + Evaporation

VOC Removal from Water



VOC-Selective Membrane (Non-Porous)

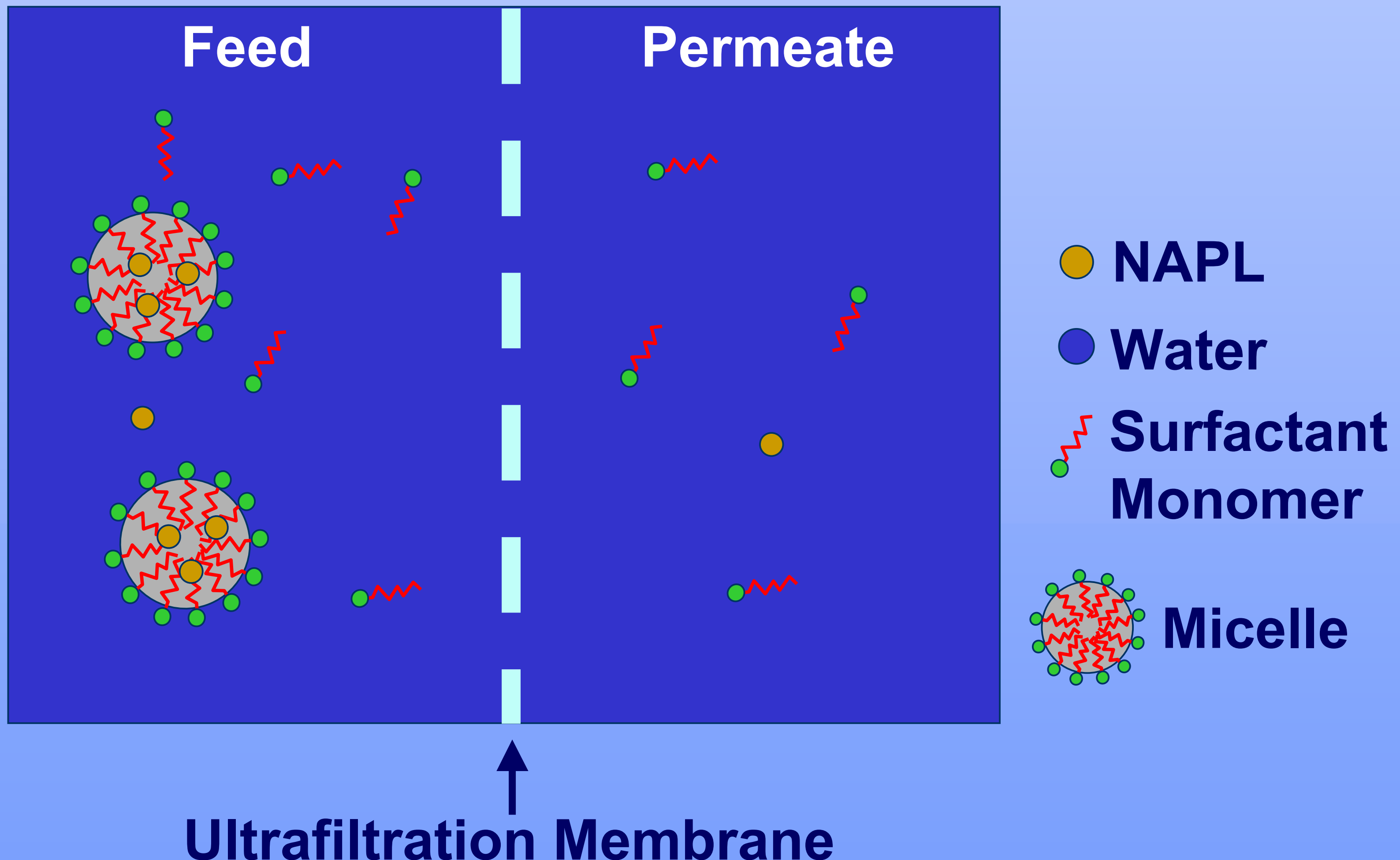
Pervaporation System Components



Surfactant Recovery Technologies

- Micellar-Enhanced Ultrafiltration (MEUF)
- Nanofiltration (NF)
- Foam Fractionation
- Precipitation
- Batch Drying

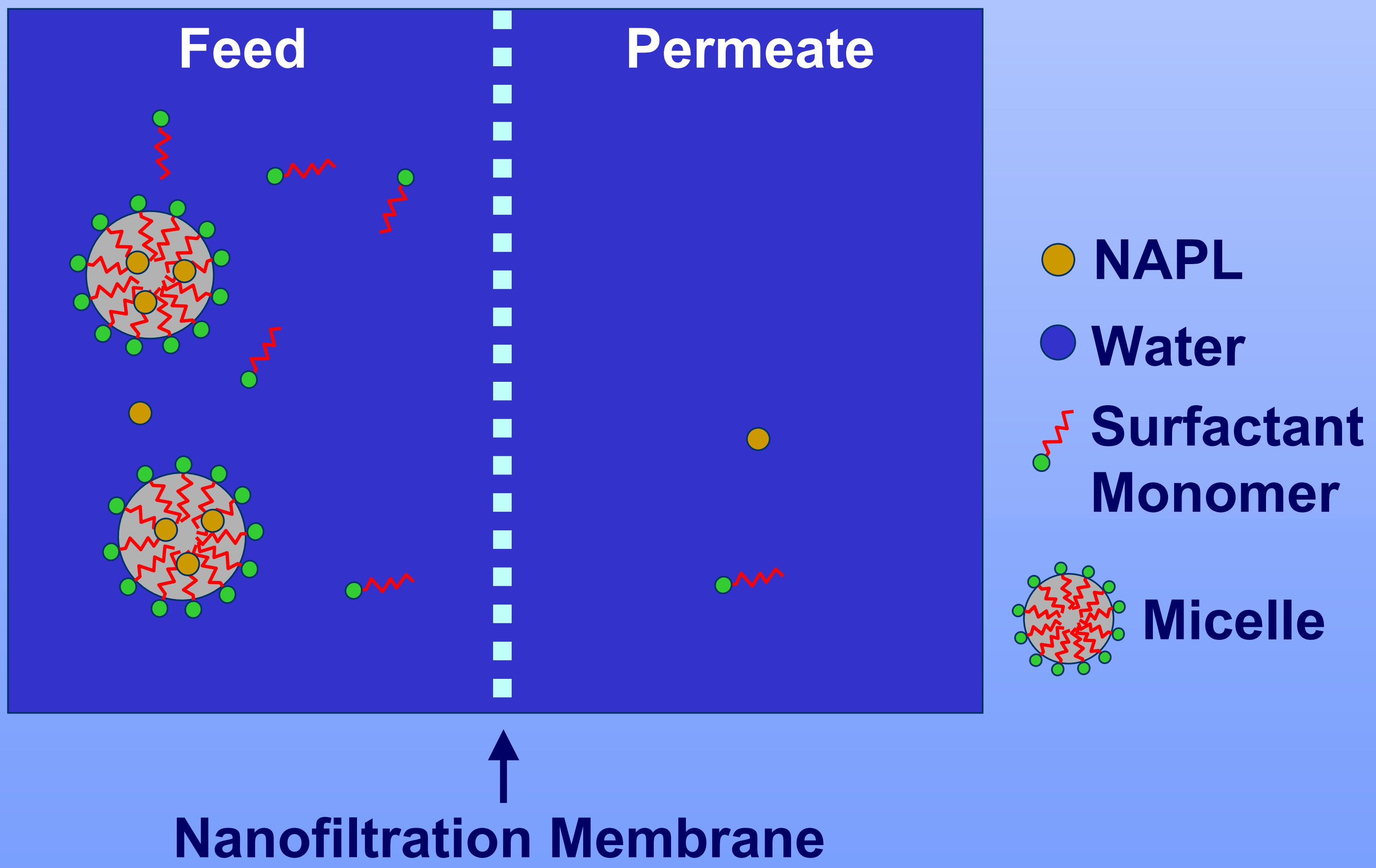
Micellar-Enhanced Ultrafiltration (MEUF)



Micellar-Enhanced Ultrafiltration (MEUF)

- Recovers
  - Surfactant micelles
- Advantages
  - Low cost
  - High % recovery for low CMC surfactant
  - Commercially available
- Disadvantages
  - Surfactant in permeate (further treatment and material loss)
  - Miicelle recovery may concentrate contaminants and cations

Nanofiltration (NF)



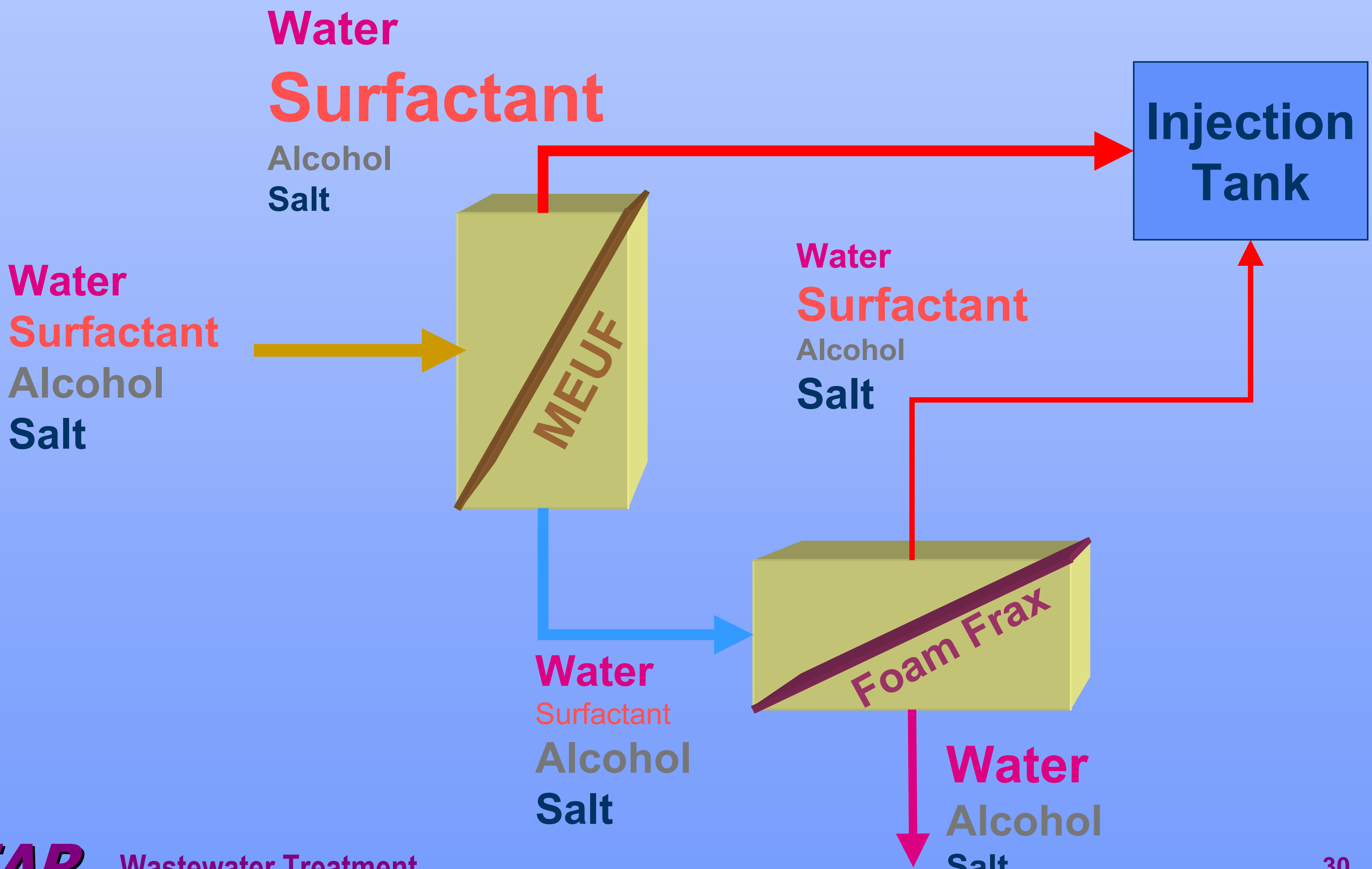
Nanofiltration (NF)

- Recovers
  - Monomers and micelles
- Advantages
  - High % recovery of even monomers
  - Commercially available
- Disadvantages
  - Low membrane flux
  - Higher pressures required
  - Moderate to high cost

Foam Fractionation

- Recovers
  - Surfactant monomer
- Advantages
  - Low cost
  - Can recover monomer
- Disadvantages
  - Not for bulk removal
  - Best for monomer recovery

Hybrid Surfactant Recovery Process



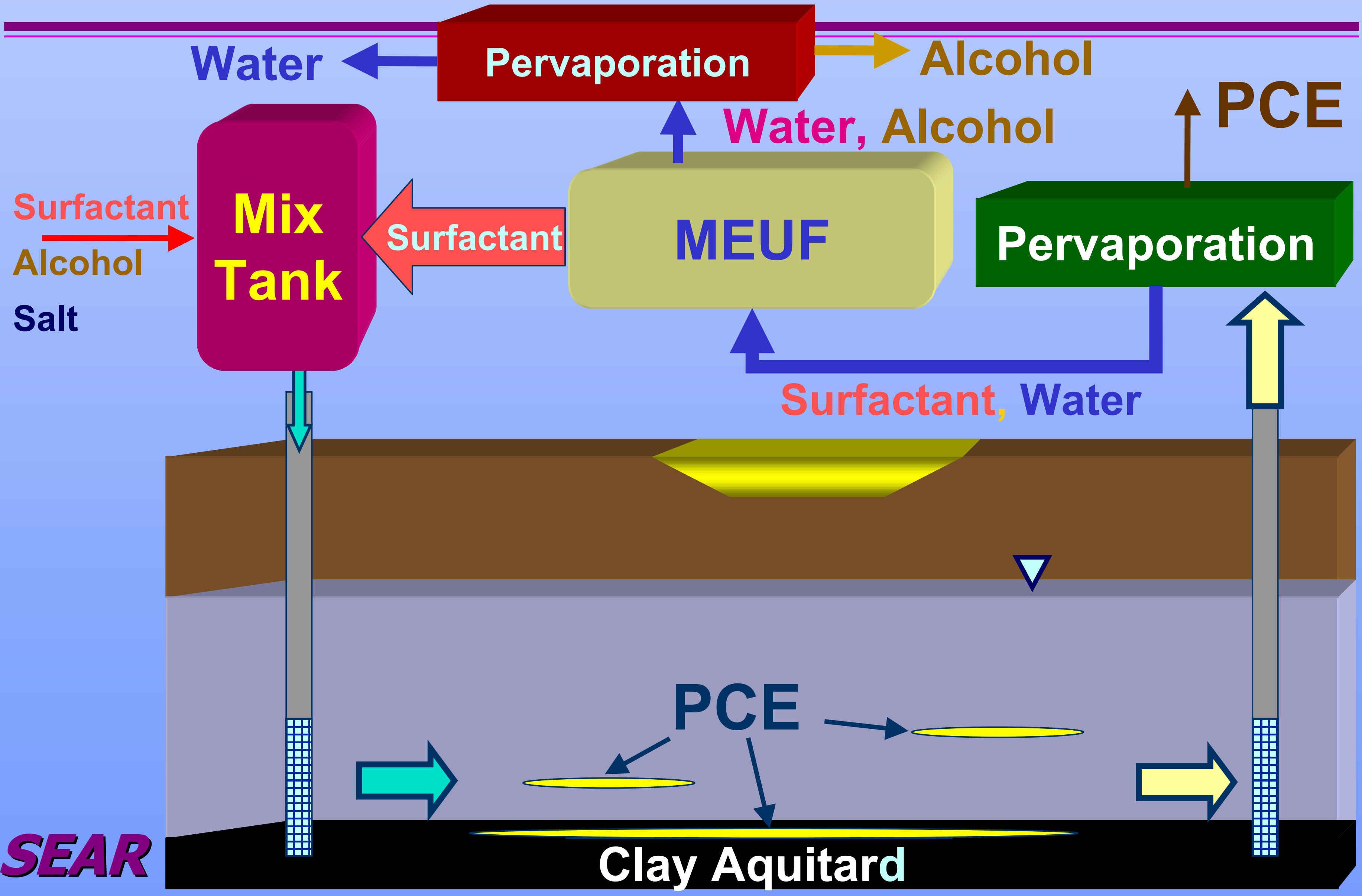
Alcohol Recovery Technologies

- Pervaporation
- Distillation
- Steam Stripping

ESTCP Field Demonstration

- MCB Camp Lejeune
  - Soil contaminated with dry-cleaning solvent (PCE)
- Objective: To remove PCE from soil using SEAR process and to recycle/reuse the surfactant

ESTCP Field Demonstration



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MCB Camp Lejeune Demonstration Participants

- U.S. Navy
- U.S. EPA
- Duke Engineering & Services
- University of Oklahoma
- University of Texas at Austin
- Baker Environmental
- IT Group (OHM, IT Corp.)

U.S. EPA's MCB Camp Lejeune Pervaporation Field Demonstration

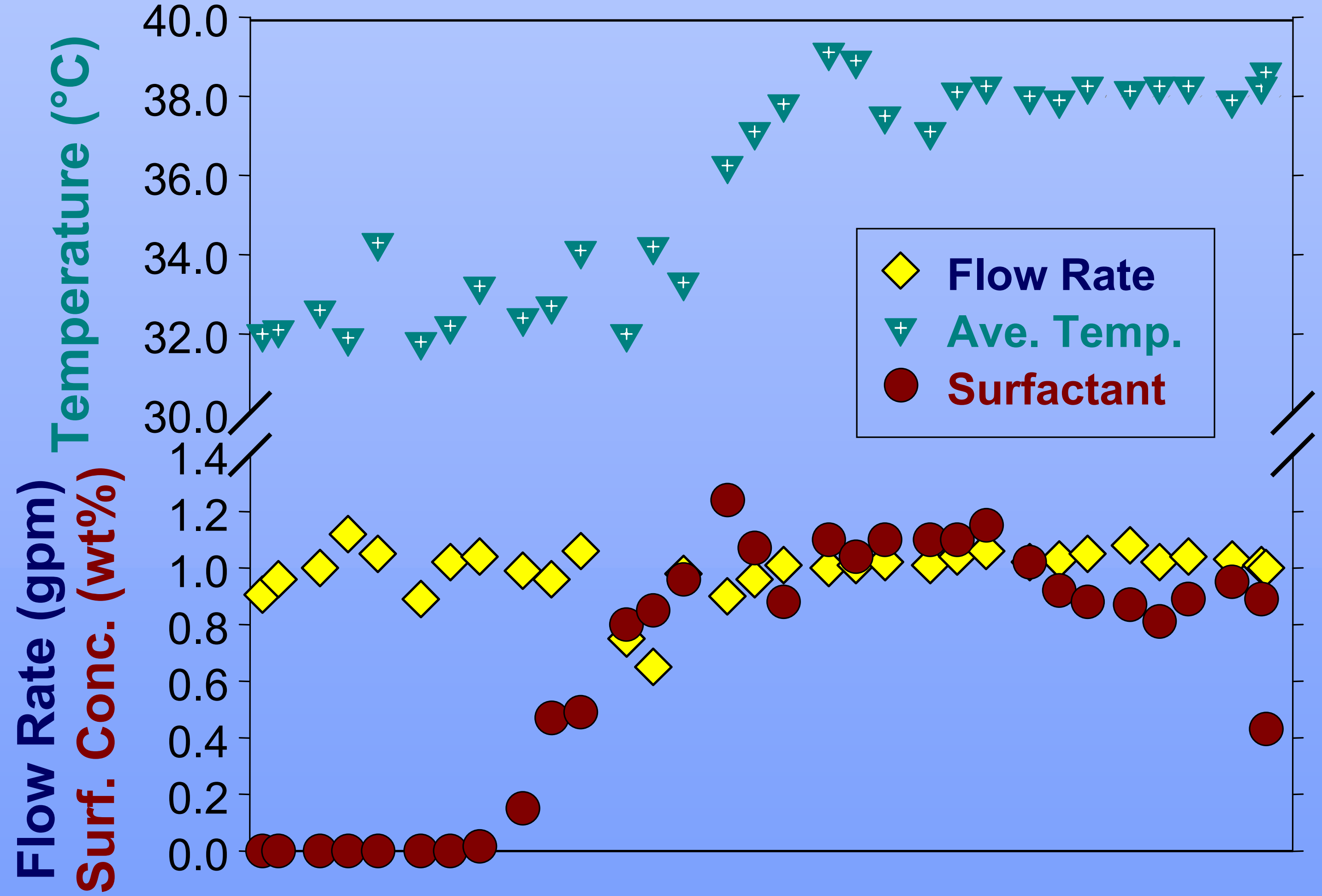
U.S. EPA's MCB Camp Lejeune Pervaporation Unit

MCB Camp Lejeune Pervaporation Systems

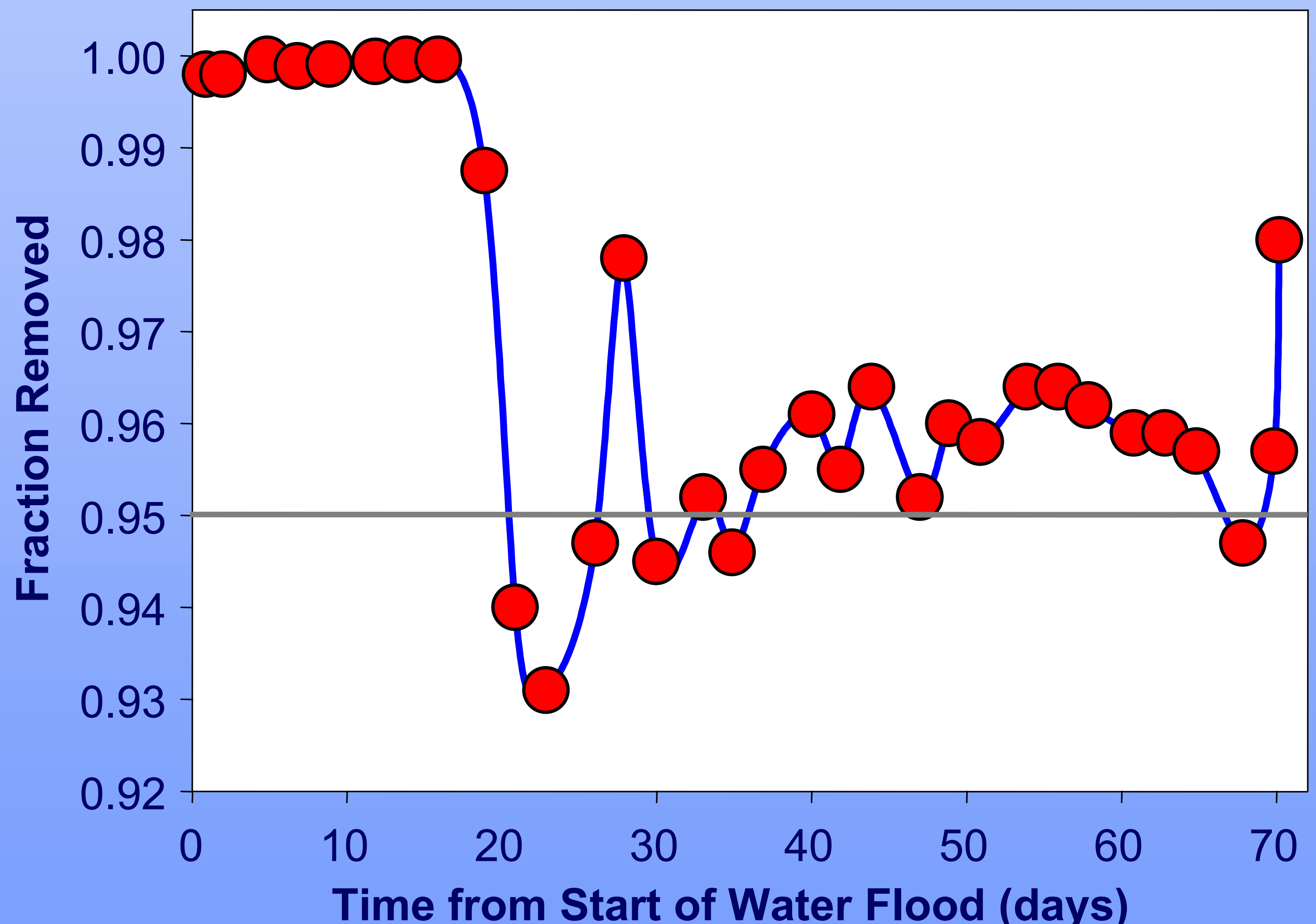
MCB Camp Lejeune Extracted Fluid

- Flow = 1.0 gpm
- Surfactant = 0 to 1.2 wt%
- Isopropyl alcohol = 0 to 4.5 wt%
- PCE = 35 to 1,000 mg/L
- Other VOCs $<$ 5 mg/L
- pH = 4.0 to 4.4
- Ca^{2+} = 250 mg/L
- Fe^{2+} = 15 mg/L

Process Parameters for MCB Camp Lejeune Wastewater System



PCE Removal by MCB Camp Lejeune Pervaporation Field Unit (95% Removal Objective)

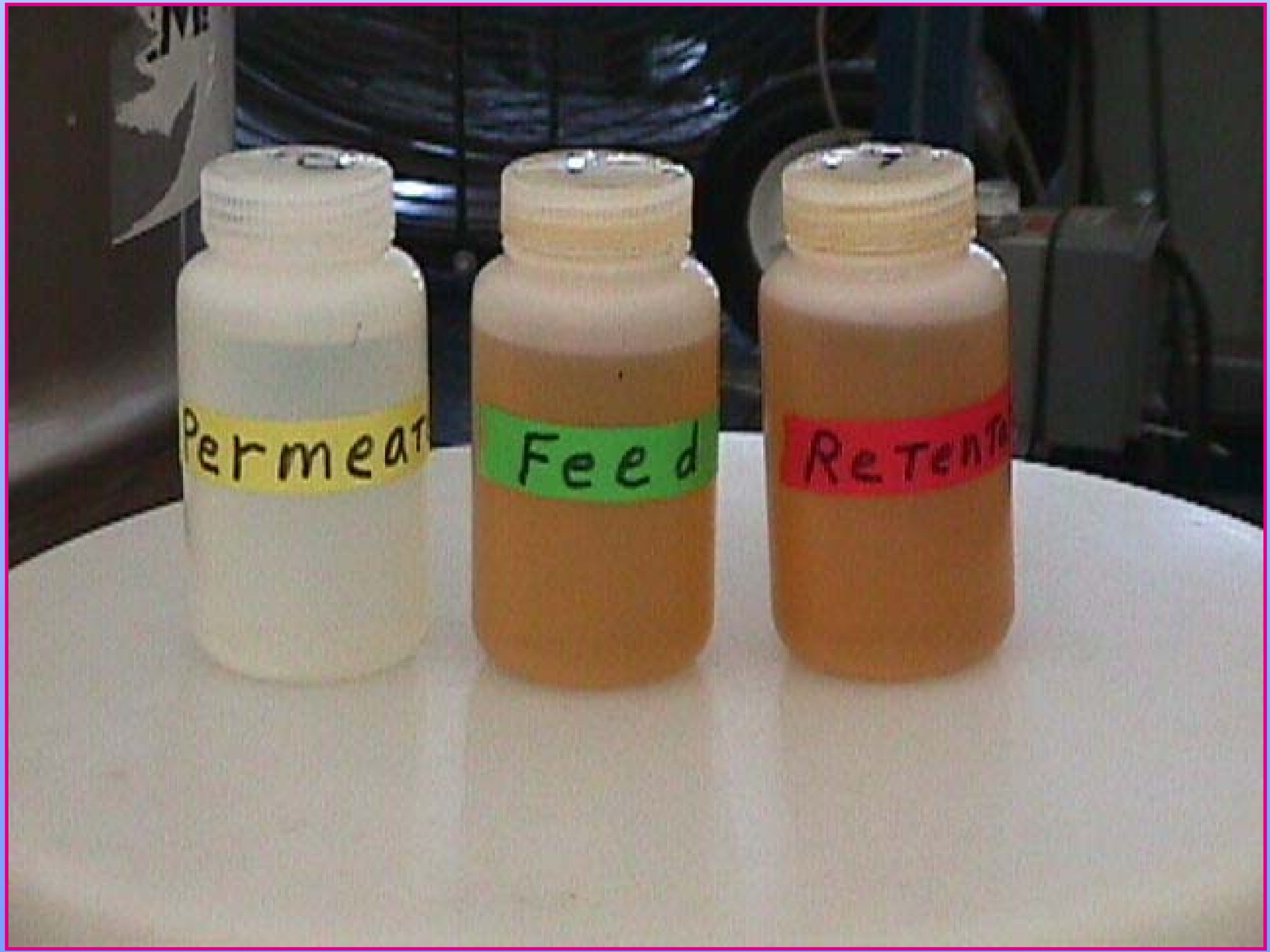


EPA Camp Lejeune Pervaporation Unit: Performance

- PCE Removal
  - Groundwater: 99.94 +/- 0.02 %
  - Surfactant Solution: 95.8 +/- 0.3 %
  - 160 kg (360 lb) PCE removed
- Varsol (Mineral Spirits) Removal
  - Groundwater: < MDL
  - Surfactant Solution: approx. 50%

MEUF Equipment at MCB Camp Lejeune (University of Oklahoma)

MCB Camp Lejeune MEUF Samples



MCB Camp Lejeune MEUF Performance

- 76% surfactant recovery
- 3,800 lb surfactant recovered
- Adversely affected by alcohol

Reinjection Issues

- Reformulation of surfactant
  - Need to maintain desired properties of mixture
- Reinjection of some contaminant
  - No process will remove 100%
- Return of groundwater ions and reaction products to injection wells
  - For example, precipitation of iron caused by oxidation of Fe^{2+}

Competing Scale Issues

High Flow & Short Duration

vs.

Low Flow & Long Duration

- Low cost answer
  - Depends on lease terms/capital costs and operating expenses
  - Also depends on optimum ranges for the technologies

Conclusions

- Wastewater treatment <u>must</u> be considered when designing SEAR process
- Material savings, cost savings, and disposal cost avoidance may motivate treatment decisions
- Technologies are available to perform the necessary separations
- Added technical and logistical issues complicate implementation

Any Questions?

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